https://doi.org/10.37815/rte.v37nE1.1339
Original articles

Blockchain-based Application for a Sustainable University: Systematic Review and UCE-Camp Proposal for the Academic Processes of Higher Education Institutions

Aplicación basada en Blockchain para una Universidad Sostenible: Revisión Sistemática y Propuesta UCE-Camp para los Procesos Académicos de Educación Superior

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Sent: 2025/06/16
Accepted: 2025/08/20
Published: 2025/10/15

Abstract

This study aims to evaluate the potential of blockchain technology in higher education, with a particular focus on its benefits and challenges in academic processes. A systematic literature review was conducted, analyzing 42 key studies selected from a total of 533 academic publications over the past six years. The results indicate that blockchain applications are primarily concentrated in secure certificate issuance, the enhancement of teaching and learning environments, and the transparent management of academic credits and scholarships. The main contribution of this research is the presentation of a comprehensive and up-to-date overview of blockchain integration in the educational domain. Furthermore, it introduces the UCE-Camp model as a sustainable framework designed to improve the efficiency, transparency, and quality of academic operations. The study also identifies existing gaps and challenges, outlining future research directions for the broader adoption of blockchain in higher education.

Keywords: blockchain, academic process, e-government, higher education, issuance of academic certificates, sustainability.

Summary: Introduction, Methodology, Results, Discussion and Conclusions.

How to cite: Jimbo, P., Morales, M., Jimbo, M., Morales, S. & Toscano, S. (2025). Blockchain-based Application for a Sustainable University: Systematic Review and UCE-Camp Proposal for the Academic Processes of Higher Education Institutions. *Revista Tecnológica - Espol, 37(E1), 162-183.* https://doi.org/10.37815/rte.v37nE1.1339

Resumen

Esta investigación tiene como objetivo analizar el potencial de la tecnología blockchain en la educación superior, enfocándose en sus beneficios y desafíos dentro de los procesos académicos. Se realizó una revisión sistemática de literatura, se examinaron 42 estudios relevantes seleccionados entre 533 publicaciones académicas de los últimos seis años. Los hallazgos revelan que las principales aplicaciones de blockchain se centran en la emisión segura de certificados, la mejora de los entornos de enseñanza-aprendizaje y la gestión transparente de créditos y becas. Como principal contribución, el estudio ofrece una visión integral y actualizada sobre el uso de blockchain en el ámbito educativo, y propone el modelo UCE-Camp como una solución sostenible para optimizar la eficiencia, transparencia y calidad de los procesos académicos. Además, se identifican brechas y desafíos que abren nuevas líneas de investigación para su implementación futura.

Palabras clave: cadenas de bloques, proceso académico, gobierno electrónico, educación superior, emisión de certificados académicos, sostenibilidad.

Introduction

Several studies on blockchain-based technology (BCT) have explored prototypes, case studies, and theoretical frameworks across diverse sectors, including supply chain management, business, healthcare, energy, utilities, e-government, Internet of Things (IoT), security and privacy, data management, and—importantly—education. These domains represent key research trends as identified by Casino, Dasaklis, & Patsakis (2019) and Higinio Mora et al. (2021).

In the educational sector, blockchain initiatives remain in an early developmental stage but hold significant potential to transform student information systems. The primary areas of application include certification management, credit and commission transfers, tracking of skills and learning outcomes, professional capability assessment, collaborative learning environments, digital tutoring, and evaluation processes (Rojas, Gayoso Martínez, & Queiruga-Dios, 2020). Additional use cases involve incentive-based learning programs and the verification of educational content authenticity.

The integration of blockchain in education —particularly through ePortfolios— has garnered increasing attention in academic literature. Trejo (2019) highlights that ePortfolios foster active learning and digital competence, while blockchain's decentralized and secure architecture enhances transparency and reliability in educational data management (Cortés, Pinto, & Atrio, 2015). Furthermore, blockchain facilitates interoperability among institutions, enabling seamless exchange of credentials and academic records.

Blockchain-based ePortfolios also address challenges in managing roles and resources within modern educational systems. Tinoco et al. (2023) demonstrate the utility of their approach in issuing and verifying academic credentials and communicating competencies. Blockchain emerges as a robust solution for secure information processing and storage, mitigating risks such as plagiarism and inefficient resource management.

Despite its promise, blockchain adoption in education faces notable limitations. Oyelere et al. (2020) report limited awareness and usage of blockchain within the academic community, indicating a lack of widespread understanding and adoption. Additionally, as an emerging and relatively untested technology, blockchain suffers from the absence of standardized frameworks, which may lead to security vulnerabilities, hacking risks, and unintended data exposure.

These limitations underscore the importance of adequate preparation and technological literacy to ensure successful implementation. Tinoco et al. (2023) identify key challenges in higher education that blockchain seeks to address, including credential verification—critical in combating academic fraud—and secure, permanent storage of academic records and learning achievements (Rivera-Vargas, 2020).

The significance of this study lies in its contribution to innovation and improvement of academic processes in higher education institutions (HEIs). It proposes a tailored model—UCE-Camp—that aligns with the specific needs and operational characteristics of universities, aiming to facilitate effective integration of blockchain. This technology offers distinct advantages that support institutional sustainability, such as enhanced security, transparency, and efficiency in data management.

To support this proposal, a systematic literature review was conducted, analyzing studies published between 2018 and 2024 that explore blockchain-based applications, methods, or frameworks within HEI-managed academic processes.

This paper provides a comprehensive overview of blockchain technology and its connection to academic processes, followed by a detailed explanation of the methodology applied in conducting a systematic literature review. The subsequent section presents the analysis of the reviewed literature and the results obtained. These findings are then discussed in light of the challenges that must be addressed to enable broader adoption of this technology within higher education institutions. Additionally, the UCE-Camp proposal is introduced as a sustainable model for the university. The paper concludes by summarizing the main insights and offering recommendations for future research.

Blockchain and Academic Processes

Blockchain, also known as distributed ledger technology, is recognized as a foundational innovation (Conti, Sandeep, Lal, & Ruj, 2018) that underpins the development of cryptocurrencies and virtual currencies by enabling data immutability and integrity (H. Mora, Morales-Morales, Pujol-López, & Mollá-Sirvent, 2021). It operates by storing electronic records in a distributed, immutable, and verifiable database accessible to all computers within the network—referred to as nodes—which are responsible for validating transactions and thereby replacing the function of a centralized authority (Mohan, 2019).

A notable feature of blockchain technology is its resistance to manipulation, as it eliminates the need for a central entity to authorize or restrict transactions (Swan, 2018). This decentralized structure addresses the issue of trust among market participants and ensures the integrity and transparency of transactions (Alnafrah & Mouselli, 2021).

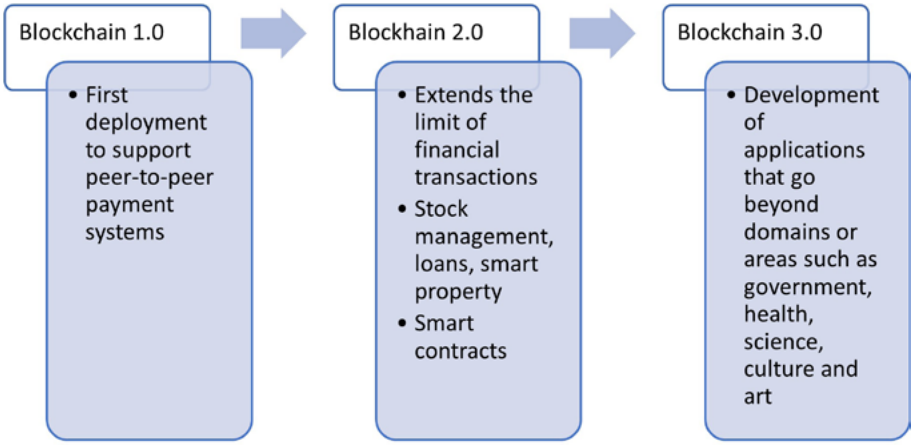
Transactions are recorded chronologically in the ledger, and as the chain expands, the difficulty of falsification increases (Tahar, Hammi, Bellot, & Serhrouchni, 2018). Nodes aggregate transactions into blocks and validate their inclusion in the chain through consensus mechanisms—cryptographic algorithms designed to ensure agreement across the network (Zhang & Lee, 2020).

Blockchain platforms can be tailored to specific purposes through the integration of smart contracts, which are fundamental components that inherit the blockchain immutability. Smart contracts facilitate automatic execution of predefined instructions based on the logic agreed upon by participants, eliminating the need for trusted intermediaries (Lucas Palma, Gomes, Vigil, & Martina, 2019).

The evolution of blockchain technology has progressed through multiple stages, as illustrated by Alammary et al. (2019) and Chen, Xu, Lu, & Chen (2018) in Figure 1. At its most advanced stage, blockchain applications have been deployed across various sectors, including government, healthcare, and education.

Figure 1

Evolution of Blockchain Technology



Higher education is currently situated within a context of increasing internationalization and intense global competition, necessitating greater efficiency in institutional processes—particularly in the management of academic records (Van Damme, 2001). Within this framework, several challenges persist, including student authentication, credential verification, degree issuance, and the transfer of academic information across institutions. These issues often stem from paper-based systems, which introduce vulnerabilities such as susceptibility to manipulation, increased verification burdens, and a higher demand for human resources (Alnafrah & Mouselli, 2021). Higher education institutions (HEIs) frequently rely on physical documentation and centralized storage methods, rendering them vulnerable to fraud (Rane, Singh, Singh, & Amarsinh, 2020). Moreover, traditional systems exhibit limitations in terms of auditability and external verification (Badr, Rafferty, Mahmoud, Elgazzar, & Hung, 2019).

The rapid advancement of digital technologies has both amplified opportunities and increased risks. One notable concern is the increased ease with which academic fraud can be committed. In educational settings, it is possible to falsify student records, such as registering a course as completed when the requirements have not been met (Lutfiani, Apriani, Nabila, & Juniar, 2022). Document forgery—including academic records and certificates issued by HEIs—can negatively impact organizations that unknowingly admit individuals lacking the necessary qualifications (Rane et al., 2020). According to Forbes, fraudulent academic documentation is estimated to cause global damages of approximately USD 7 billion annually, underscoring the urgency for technological solutions. This context has accelerated interest in blockchain-based technology (BCT), which holds the potential to transform how universities manage academic resources (Rustemi, Dalipi, Atanasovski, & Risteski, 2023).

Given these challenges, universities must align their digital, institutional, and administrative infrastructures with emerging technologies. Several studies suggest that blockchain offers substantial benefits across various domains due to its inherent properties—immutability, fault tolerance, decentralization, and auditability (Turkanović, Hölbl, Košič, Heričko, & Kamišalić, 2018). Specifically, BCT can enhance fraud detection in academic institutions,

not only in certificate verification but across all academic records (Lutfiani et al., 2022). Its implementation may lead to improved educational outcomes, streamlined administrative procedures, and greater institutional transparency (Rustemi et al., 2023).

In the context of higher education, various blockchain-based solutions have been proposed. These will be examined in detail in the following section, which presents the findings of a systematic literature review conducted by the authors.

Methodology

This study addresses the set objectives through a systematic literature review, which involves a series of activities related to the identification, evaluation, and interpretation of a topic of interest, providing a framework for the research. To achieve this, the method proposed by Kitchenham (2014) define the following stages:

- Planning: Identify needs, define relevant databases, and determine key search terms.
- Execution: Determine inclusion/exclusion criteria and manually add relevant studies.
- Presentation: Summarize and present select studies.

During the planning phase, this research focused on two core concepts: blockchain and academic processes. These concepts were combined to form primary search keywords. The selected databases for the literature review included Google Scholar, ScienceDirect, IEEE Xplore, and arXiv.

The choice of these databases is justified by their complementary strengths and broad coverage across scientific and technical disciplines. Google Scholar provides a multidisciplinary search capability, enabling access to a wide range of academic sources, including peer-reviewed articles. Its citation tracking feature also facilitates the identification of influential and emerging works. ScienceDirect, managed by Elsevier—one of the world's leading scientific publishers—offers access to high-quality, peer-reviewed research that is recognized within the academic community. IEEE Xplore is essential for engineering and technology-related studies, granting exclusive access to conference proceedings and publications from the Institute of Electrical and Electronics Engineers (IEEE). Lastly, arXiv serves as a repository for preprints, allowing early access to cutting-edge research prior to formal publication, which is critical for capturing the latest trends and developments.

In the execution phase, the criteria defined during the planning stage were systematically applied. The review process was structured through a series of iterations, incorporating inclusion and exclusion criteria as follows: (i) inclusion of journal articles and book chapters, (ii) screening of titles and abstracts, and (iii) full-text review of selected articles. Additionally, relevant studies were incorporated using the snowballing method as proposed by Wohlin (2014).

The limitations of this study include the restriction to English-language publications and the use of only four academic digital databases. Within these sources, only journal articles and book chapters published between 2018 and 2024 were considered. A summary of the applied criteria is presented schematically in Table 1.

Table 1
Inclusion/Exclusion Criteria

TYPE OF CRITERION	DESCRIPTION OF CRITERION
Inclusion	Search criteria: "blockchain" AND "Academic processes" "Higher education" AND "blockchain" "academic" AND "blockchain"
Inclusion	Journal articles and book chapter
Inclusion	Articles in English language only
Inclusion	Publications from 2018 to 2024
Exclusion	Abstract does not provide relevant information
Exclusion	Duplicate articles
Exclusion	Articles in another language

The search criteria for this systematic review were carefully defined to include key terms such as "blockchain," "academic processes," "higher education," and "academic," ensuring a focused and comprehensive exploration of blockchain's role within the academic domain. This strategic approach enabled broad coverage of relevant literature published between 2018 and 2024. The rationale for conducting a systematic review of scientific articles lies in the rapid technological advancements in blockchain, its growing adoption in educational contexts, and the need to examine the most current trends shaping its implementation.

This methodology ensures that the proposed model is grounded in contemporary practices and knowledge, which are essential for the sustainable and autonomous management of higher education institutions. The review maintains its rigor and relevance by selecting only peer-reviewed journal articles and book chapters written in the English language. Non-relevant abstracts, duplicate entries, and non-English publications were excluded to preserve methodological integrity and avoid information overload or selection bias. The deliberate omission of additional search terms was intended to maintain the specificity of the review, ensuring that the research remains sharply aligned with its core objectives and is not diluted by peripheral data. This balance between inclusion and exclusion is critical to conducting a systematic review that is both thorough and impartial, effectively addressing the research questions without compromising clarity.

Furthermore, inclusion criteria were established for selecting studies, emphasizing thematic relevance, methodological rigor, recency, academic impact, and diversity of perspectives. These criteria ensure that the selected works make a meaningful contribution to the analysis of blockchain applications in higher education, providing a robust and representative foundation for the development of this study.

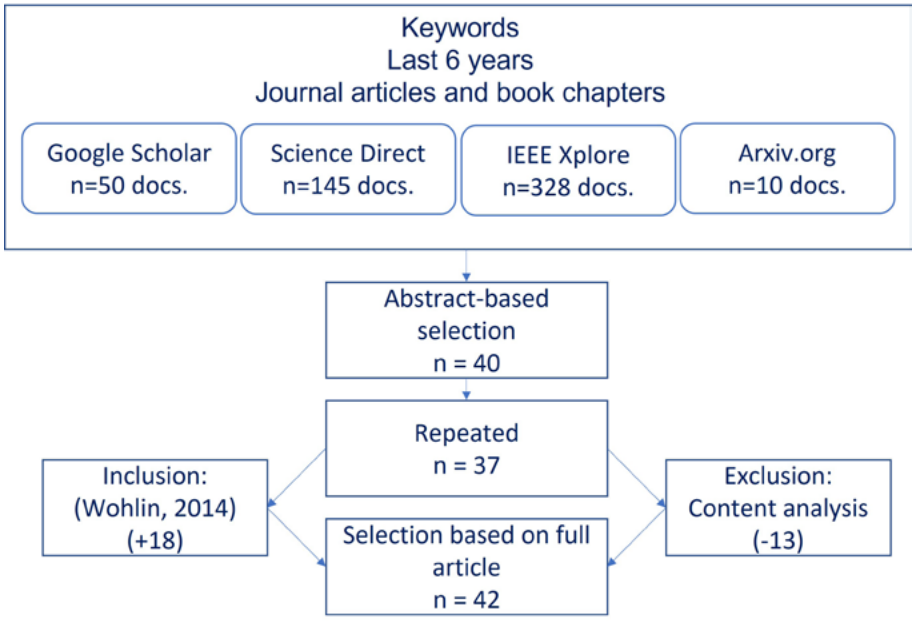
To guide the scope and direction of the research, a set of research questions was formulated in alignment with the study's overarching objective. The following questions were defined:

- What relevant works and research have been conducted on blockchain applied in the academic and higher education field?
- What are the benefits and challenges associated with implementing blockchain in academic processes in higher education institutions?

Figure 2 illustrates the extraction process and the different results obtained in each iteration.

Figure 2

Document Extraction Scheme



This methodological approach ensures that the selected studies are directly relevant to the intersection of blockchain technology and higher education, thereby upholding the quality and relevance of the review. The exclusion of duplicate entries and the restriction to recent, English-language publications from 2018 to 2024 enhance the timeliness and contextual accuracy of the sample. Additionally, the removal of non-relevant abstracts minimizes bias and prevents information overload.

Although the final sample size is relatively small, each article offers substantial contributions to the existing body of knowledge, enabling a comprehensive and up-to-date understanding of the topic. The representativeness of the selected studies ensures alignment with the research questions, resulting in a systematic review that is both methodologically sound and analytically robust. This facilitates a nuanced and meaningful examination of the literature.

In the presentation phase, the findings are synthesized and categorized according to the typology proposed by Alammary, Alhazmi, Almasri, & Gillani (2019). A detailed analysis of these results is provided in Section 4.

Literature Review

In this study, a total of 42 scientific articles and book chapters directly related to the proposed objectives have been analyzed. These research works describe concepts, case studies, or proposals related to Blockchain Technology (BCT) within academic contexts, especially in higher education institutions. Table 2 presents the most relevant findings of each study, classified according to the typology described by Alammary et al.(2019).

Table 2

Summary of relevant findings

TYPE OF STUDY	REFERENCE	RELEVANT FINDINGS
Academic qualifications management	(Awaji & Solaiman, 2022)	Describes a BCT-based system that generates a verifiable record of achievements of higher education students in a way that accelerates the authentication and validation process of such certificates.
Copyright management	(Mohan, 2019)	Proposes the use of a centralized blockchain (permissioned blockchain) that incorporates incentive structures for readers and reviewers in academia as a solution to mitigate misconduct in scientific production. It encompasses a reputation system and proof of value as fundamental components of the blockchain.
Learning Outcomes Management	(Nousias, Tsakalidis, Michoulis, Petridou, & Vergidis, 2022)	Designs a verification system called VerDe (Verified Degrees) based on BCT and BPMN technology, which enables secure registration of academic qualifications.
Evaluation of the professional capacity of the students	(Zhao, Liu, & Ma, 2019)	The research presents a study of a BCT-based system for assessing students' skills, using a clustering algorithm to analyze academic performance and other extracurricular achievements.
Support for lifelong learning	(Sharples & Domingue, 2016)	It proposes a blockchain-based registry to recognize intellectual effort and create a reputational reward system.
Fee and credit transfer management	(Srivastava et al., 2018)	It proposes a blockchain-based platform for the interaction of multiple HEIs (Higher Education Institutions) that allows the verification of certificates and academic credits, which can be transferred between different organizations through tokens.
Skills management	(Williams, 2019)	Envisions a scenario where universities will outsource parts of their course delivery and evaluation to remain competitive in a technology-driven environment motivated by blockchain.
Improving student interactions in e-learning	(Bdiwi, De Runz, Faiz, & Cherif, 2018)	Proposes a model based on a ubiquitous learning environment that delivers educational services on a blockchain platform, integrating this technology with IoT.
Protection of learning objects	(Hori et al., 2018)	Proposes a decentralized e-learning platform called CHiLO that utilizes e-books and other learning objects, is based on blockchain technology, uses virtual currencies, and considers copyright rights.
Obtaining digital guardianship consent	(Gilda & Mehrotra, 2018)	Proposes a more efficient data authorization framework based on blockchain technology (BCT) to manage permissions in a public school.
Rate and credit transfer management	(Asamoah et al., 2023)	The study proposes a platform based on BCT and crowdsourcing for student loans in which investors will be incorporated to provide funds to higher education students
Permissions and credentials management	(Tariq, Haq, & Ali, 2022)	Presents Cerberus, a prototype for BCT-based credential verification. Addresses real fraud scenarios and credential revocation through features like data privacy and transcript verification
Certificate management	(Alnafrah & Mouselli, 2021)	Proposes a blockchain scheme in an HEI using public and private keys for each student, through which they can access academic records that have been validated by the institution and can be accessed by any organization worldwide.
Certificate management	(Guerreiro, Ferreira, Fonseca, & Correia, 2022)	Integrates an open-source academic management system with a blockchain platform to record certificates and diplomas awarded by an HEI.
Certificate management	(Jaramillo & Piedra, 2020)	Proposes a BCT-based model for the registration of academic certifications. Identifies actors, processes, and components for implementation.
Certificate management	(Luis Palma, Vigil, Pereira, & Martina, 2019)	It implements a blockchain-based system for registering degrees and academic credits in the higher education system, utilizing the Brazilian Public Key Infrastructure (PKI).
Certificate management	(Morales-Morales, Rosero-Correa, & Morales-Cardoso, 2020)	Proposes a blockchain-based application that enables the replication of the degree registration process issued by a HEI without the need for a central verifying entity.
Certificate management	(Badr et al., 2019)	Proposes a model for the transfer and verification of tamper-proof academic records.
Certificate management	(Rane et al., 2020)	Conducts a research study to validate university certificates in local and international contexts.
Certificate management	(Lutfiani et al., 2022)	Proposes a certificate validation system based on blockchain technology with the purpose of preventing and/or detecting fraud in such academic documents.
Certificate management	(Rustemi et al., 2023)	Conduct a systematic study focused on academic certificate verification systems. Describes the most important challenges for its deployment and develops a taxonomy with its main themes.

TYPE OF STUDY	REFERENCE	RELEVANT FINDINGS
Certificate management	(Rasool et al., 2020)	Presents a prototype based on BCT and optical character recognition for the verification of academic degree titles and in this way generate efficiency in the mass presentation of degree records
Certificate management	(Le Van Tan, & Pham Minh Hung, 2024)	Proposes a blockchain-based system for managing academic certificates with QR code verification.
Certificate management	(Oluwaseyi, A, 2024)	Designs a blockchain-based system using Ethereum and IPFS to verify university certificates securely.
Literature review BCT in education	(Rojas et al., 2020)	Analyzes various fields of application of BCT within the education domain and describes interesting pilot projects conducted in educational institutions.
Literature review BCT in education	(Alammary et al., 2019)	Conducts a systematic review study that addresses BCT applications in the field of education and the benefits and challenges to be faced.
Literature review BCT in education	(Tahora, Saha, Sakib, Shahriar, & Haddad, 2023)	Through an SLR study, it evaluates the benefits of implementing BCT technology for management in higher education, analyzing limitations and challenges in the educational field.
Literature review BCT in education	(Zou, Meng, Zhang, Zhang, & Li, 2020)	Through a comprehensive study, it analyzes the current state of BCT academic research and its application scenarios. Recognizes the advantages and challenges of this technology and discusses future trends related to blockchain
Literature review BCT in education	(Ocheja, Agbo, Oyelere, Flanagan, & Ogata, 2022)	Conduct a qualitative bibliometric study. Highlights a temporal analysis, emerging themes and practical cases of adoption and integration with educational technologies
Literature review BCT in education	(Silaghi, D. L., & Popescu, D. E, 2024)	Conducts a systematic review of blockchain initiatives in higher education, comparing them to institutional best practices.
Literature review BCT in education	(Tahora, S., Saha, B., Sakib, N., Shahriar, H., & Haddad, H.2024))	Critically analyzes the benefits, challenges, and risks of using blockchain in the higher education ecosystem
Management of transfers and credits	(Bedi, Gole, Dhiman, & Gupta, 2020)	Describes a blockchain-based application that enables transparent and traceable management of scholarship applications awarded to students by a government school program in India.
Management of transfers and credits	(Turkanović et al., 2018)	Proposes a blockchain-based platform called EduCTX based on the European Credit Transfer and Accumulation System (ECTS).
Management of competences and learning results	(Lizcano, Lara, White, & Aljawarneh, 2020)	It evaluates a decentralized model for transactional management of content, teaching, and assessed competencies involving different stakeholders such as students, instructors, and employers.
Management of competences and learning results	(Chen et al., 2018)	It describes some blockchain applications in the academic environment and proposes initiatives to improve or motivate teaching-learning environments.
Management of competences and learning results	(Jirgensons & Kapenieks, 2018)	It describes various models from countries within the European Union (EU) that enable the management and validation of students' skills and knowledge.
Management of competences and learning results	(Wu & Li, 2018)	Proposes a model for assessing operational skills in an e-commerce testing environment using a blockchain platform.
Management of competences and learning results	(Chaudhari, S., & Shirole, M., 2024)	Reviews how blockchain can enhance the management of academic records and learning outcomes in higher education.
Learning Outcomes Management	(Li & Ma, 2021)	Proposes a secure method for storing and sharing information from educational records with high efficiency, availability and privacy
Learning Outcomes Management	(Garg, 2023)	Proposes registering academic history on a BCT platform with validators in encrypted format
Rewarding / recognition of academic activities	(Ayman et al., 2023)	Presents the design of a decentralized BCT-based application that promotes knowledge sharing and encourages collaborative academic contribution through rewards in a higher education environment
Rewarding / recognition of academic activities	(Battah, Salah, Jayaraman, Yaqoob, & Khalil, 2023)	It proposes a solution based on BCT for the academic ranking of institutions that is based on transparency, traceability, trust and decentralization considering that currently there is weakness in indicators based on academic and employer reputation.

These findings are significant as they reflect the diversity and depth of blockchain technology's (BCT) application in the educational field. Each study contributes to a different aspect of how BCT can enhance, innovate, or solve existing problems in higher education.

Referring to studies on copyright management and certificate management, they demonstrate how BCT can increase transparency, security, and efficiency in the issuance and verification of academic credentials. It is crucial in a world where fast and reliable verification of qualifications is increasingly important for employers and educators. The proposal of a reputation system and proof-of-stake as fundamental components of the chain to mitigate misconduct in scientific production directly addresses the challenges of academic integrity.

Studies on learning outcome management and e-government process optimization illustrate BCT's potential to improve the administration and accessibility of academic records, as well as to integrate educational systems with governmental initiatives. BCT can play a significant role in standardizing and enhancing educational and governmental processes.

Furthermore, studies focusing on the assessment of students' professional competencies and the management of learning outcomes demonstrate how blockchain technology (BCT) can be effectively utilized to securely evaluate and record students' skills and achievements—an essential component for workforce development and lifelong learning. Each of these studies provides compelling evidence of BCT's potential to address specific challenges and enhance the quality and efficiency of higher education systems. The diversity of applications and the depth of analysis presented in these works establish a strong foundation for future research and technological advancement in this emerging field.

The systematic review of blockchain applications in higher education highlights both the innovations introduced and the challenges encountered. The strengths of the reviewed studies include the development of novel approaches for certificate issuance and intellectual property management, leveraging blockchain's secure and transparent architecture. However, notable limitations persist, including the lack of longitudinal research and barriers to large-scale adoption, such as institutional resistance to change and concerns related to ethics and data privacy.

This research builds upon the existing literature to offer a critical synthesis of current findings, identifying prevailing trends and research gaps. By doing so, it contributes to the broader academic discourse and directs future investigations toward underexplored areas, providing a comprehensive evaluation of blockchain's role in higher education.

As emphasized by Grech & Camilleri (2017), it is also important to recognize that the benefits of BCT are most pronounced in specific use cases where its implementation aligns with institutional needs. The applicability of blockchain isprimarily determined by the fulfillment of key criteria, which are outlined in Table 3.

Table 3

Criteria for the application of BCT

CRITERION	DESCRIPTION
Timestamp	The information requires that the set of transactions be associated with a timestamp, source, and destination.
Multiple writers	There are multiple transaction generators/writers, meaning different organizations possibly in different physical locations.
Lack of trust	There is no trust among the actors, meaning each transaction generator would not allow others to edit their entries.
Disintermediation	The generators do not wish to transfer control of the dataset to a centralized authority for management.
Interdependence	One transaction influences the execution or outcome of another.
Defined rules	There is a defined set of rules, meaning a transaction is recorded whenever specific conditions are met, which can be independently and automatically verified
Store of value	Transactions represent assets or records with real-world value

A significant research study is presented by Lutfiani et al. (2022), who developed a reference framework for a fraud detection system in academic certificates. They conclude that BCT provides an excellent means of validating academic documents, offering quick verification compared to manual processes that are slower and require more effort from all parties involved.

There are interesting references for BCT-based applications that offer benefits, especially in certificate management. Such is the case of E-Skrol in Malaysia, which the Ministry of Education has deployed to combat the growing issue of degree fraud, particularly in public universities (Swiss Quality Consulting, 2023). Another application is Blockdemy Certs, which manages digital documents and ensures their existence, integrity, and validity through a digital signature mechanism based on Ethereum BCT (Yerramsetti et al., 2023). The OS City application by UNICEF presents an appealing proposition: it enables the recording of issuance, ranging diplomas to government licenses, on the blockchain in several countries in Latin America, aiming to support a large segment of young people with informal jobs and without formal certification (Jiménez, 2020).

One relevant study that carried out by Rustemi et al. (2023). In this, they address the potential of BCT for education under five constitutive aspects that are i) the type of blockchain platform to be used, ii) the automated process of generating academic certificates, iii) security and transparency, iv) adaptability of the platform to the educational environment, and v) enablement of key technologies.

The study by Ayman et al. (2023) elaborates an interesting proposal for academic sustainability. Through its BCT-based BlockCampus initiative, it promotes participation and information exchange among members of the academic community at E-JUST University. With the project, it not only addresses the security, privacy, and trust issues that affect HEI systems, but fundamentally promotes a cohesive and collaborative community that fosters learning, innovation and professional development of students and academic staff. To achive this, it introduces token-based reward mechanisms that recognize community contributions and provide access to services and benefits both on and off the platform. This initiative has generated a positive perception of the platform, both in terms of usefulness, ease of use, satisfaction, and trust.

Finally, it is valuable to acknowledge that several of these initiatives are supported by the United Nations Development Programme (UNDP), which promotes access to education for children to acquire the necessary skills in line with the Sustainable Development Goals (Jirgensons & Kapenieks, 2018).

Results

Approach of the studies analyzed

Within the educational domain, most blockchain technology (BCT) applications concentrate on certificate management, aiming to enhance the efficiency of administrative processes in higher education institutions (HEIs). As noted by Chen et al. (2018), these applications can be broadly categorized into two main areas: (i) formal contexts, involving the management of learning content, learning outcomes, and academic credentials; and (ii) informal contexts, encompassing the tracking of research experience, skill acquisition, and online learning activities. This dual categorization reflects a growing interest in using BCT to support lifelong learning and comprehensive academic profiling.

A recurring pattern across the literature is the emphasis on transparency, traceability, and decentralization as core benefits of BCT in academic settings. Notably, several studies propose the development of reward ecosystems that incentivize intellectual contributions. For instance, Sharples and Domingue (2016) introduce Kudos, a reputational reward currency designed to democratize recognition beyond traditional academic boundaries. Similarly, Mora et al. (2021) envision a model in which students receive BCT-based virtual currency for participating in academic or community engagement, aligning with the Sustainable Development Goals. These currencies could be used for tuition payments, access to institutional services, or even converted into fiat money, suggesting a potential shift toward value-based academic participation.

Another interesting analysis can be extracted from Table 2 by performing a classification or grouping of the models, platforms, or prototypes in which the different investigations are framed. Thus, the works carried out in accordance with the proposed application type are summarized in Table 4.

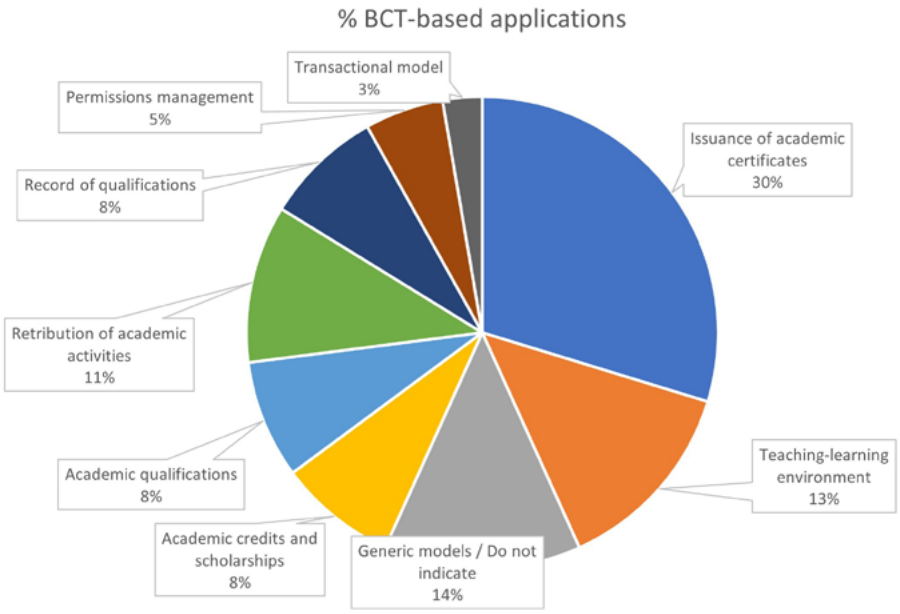
Table 4

Summary of Studies by Proposed Application Type

TYPE OF APPLICATION	REFERENCE	QTY.
Issuance of academic certificates	(Alnafrah & Mouselli, 2021), (Jaramillo & Piedra, 2020), (Luis Palma et al., 2019), (Srivastava et al., 2018), (Morales-Morales et al., 2020), (Guerreiro et al., 2022), (Badr et al., 2019), (Rane et al., 2020), (Lutfiani et al., 2022), (Rustemi et al., 2023), (Rasool et al., 2020) (Le Van Tan, & Pham Minh Hung, 2024) (Oluwaseyi, A, 2024)	13
Teaching-learning environment	(Hori et al., 2018), (Lizcano et al., 2020), (Chen et al., 2018), (Williams, 2019), (Bdiwi et al., 2018) (Silaghi, D. L., & Popescu, D. E, 2024) (Tahora, S., Saha, B., Sakib, N., Shahriar, H., & Haddad, H.2024))	7
Generic models / do not indicate	(Higinio Mora et al., 2021), (Rojas et al., 2020), (Alammary et al., 2019), (Tahora et al., 2023), (Zou et al., 2020), (Ocheja et al., 2022)	5
Academic credits and scholarships	(Bedi et al., 2020), (Turkanović et al., 2018), (Asamoah et al., 2023)	3
Academic qualifications	(Zhao et al., 2019), (Jirgensons & Kapenieks, 2018), (Awaji & Solaiman, 2022)	3
Retribution of academic activities	(Mohan, 2019), (Sharples & Domingue, 2016), (Battah et al., 2023), (Ayman et al., 2023)	4
Record of qualifications	(Nousias et al., 2022), (Li & Ma, 2021), (Garg, 2023)	3
Permissions management	(Gilda & Mehrotra, 2018), (Tariq et al., 2022) (Chaudhari, S., & Shirole, M., 2024)	3
Transactional model	(Wu & Li, 2018)	1

Figure 3

Types of BCT-based models



Quantitative analysis reveals that 29.7% of the reviewed models focus on academic certificate issuance, while 13.5% aim to optimize the teaching andlearning environment. Together, these categories represent over half of the studies analyzed (16 out of 42), as illustrated in Figure 3. The predominance of certificate-related applications highlights a key finding: BCT is primarily leveraged to enhance process efficiency and mitigate fraud risks in credential verification. This trend reflects the increasing demand for verifiable qualifications in a competitive labor market and highlights BCT's role in strengthening institutional integrity and operational transparency within HEIs.

Challenges in the academic environment

In the context of blockchain adoption within Higher Education Institutions (HEIs), a consistent pattern emerges regarding the challenges and limitations that hinder effective implementation. These difficulties are primarily associated with the lack of transparency and traceability across various academic processes. As identified by Bedi et al. (2020), the most recurrent issues include:

- Limited traceability in internal forms and procedures
- Loss of information or documentation at different stages of academic workflows
- Insufficient transparency in the dissemination of institutional data
- Difficulty for external entities to verify academic information
- Insecure storage of academic records

Key finding 1

The absence of robust mechanisms for traceability and data verification is a systemic issue in HEIs, which blockchain technology seeks to address through its inherent properties of immutability and decentralization.

Further analysis reveals additional structural and technological barriers. Grech & Camilleri (2017) highlight the lack of standardization in academic procedures and student record formats, as well as the complexity of blockchain systems—particularly regarding storage costs and consensus mechanisms. Moreover, reliance on third-party services (e.g., wallets, exchange platforms, token management systems) introduces integration challenges and potential security vulnerabilities.

Key finding 2

The fragmentation of academic systems and dependence on external technologies represent significant obstacles to seamless blockchain integration in higher education.

Technological limitations are also prominent. Alammary et al. (2019) identify several critical concerns:

- Scalability requires more efficient consensus algorithms to handle high transaction volumes
- Adoption costs, mainly linked to infrastructure transformation
- Network trustworthiness, demanding clear and enforceable data-sharing policies
- Immutability, which complicates the correction of inaccurate or outdated records

Badr et al. (2019) note that ensuring compliance with privacy regulations, such as GDPR, is a persistent challenge when storing sensitive academic data on blockchain platforms.

Key finding 3

The tension between blockchain's immutability and the dynamic nature of academic data underscores the need for flexible yet secure data governance models.

Rustemi et al. (2023) further emphasize the importance of interoperability with existing university systems and the implementation of robust cybersecurity protocols to prevent unauthorized access. A particularly critical issue involves the correction or revocation of data, given blockchain's irreversible architecture. Additionally, the precision required in defining automation rules within smart contracts is essential to ensure autonomous execution without external intervention.

Key finding 4

The technical complexity of blockchain systems, combined with the steep learning curve for institutional stakeholders, constitutes a significant barrier to widespread adoption in HEIs.

These challenges reflect the evolving maturity of blockchain technology, which remains in a developmental phase. Addressing them requires not only technical innovation but also institutional commitment to capacity building and strategic planning. A summary of these challenges is presented in Table 5.

Table 5

Challenges in deploying a BCT platform in HEI environments

TYPE OF DIFFICULTY	REFERENCE
Functional	• Poor traceability and transparency in internal processes • Academic processes with low standardization • Establish automation policies and rules • Learning curve
Information management	• Lack of transparency in the dissemination of information • Loss of information or documentation • Information privacy management • Data interoperability with other systems
Technological	• Security schemes for the storage and management of information • Complexity in the use of resources • Platform usage costs and infrastructure transformation • Technological dependence on third parties • Platform scalability • Chain immutability (revocation)

Key findings, benefits, challenges, and opportunities

The integration of blockchain technology (BCT) into Higher Education Institutions (HEIs) reveals consistent patterns and key findings that underscore its transformative potential. A recurring theme across literature is the emphasis on BCT's technical advantages, particularly the immutability of records and the decentralization of data management, which collectively enhance integrity, transparency, and trust in academic processes. Studies such as Lutfiani et al. (2022) consistently highlight the capacity of BCT to optimize critical institutional functions, including degree certification, admissions, enrollment, and evaluation procedures, thereby reducing the risk of fraud and corruption.

Key finding 1

The predominant application of BCT in HEIs centers on credential verification and process automation, reflecting a clear pattern of prioritizing administrative efficiency and data integrity.

Despite these advantages, the literature also identifies several technical challenges that must be addressed to ensure successful implementation. These include:

- Network scalability which limits transaction throughput in high-volume environments.
- Interoperability with legacy academic systems hinders seamless integration.
- Data privacy management, especially in compliance with international regulations such as the GDPR.

Key finding 2

The most frequently cited barriers to adoption are technical in nature, suggesting that institutional readiness and infrastructure modernization are critical prerequisites for BCT deployment.

To mitigate these challenges, the following technical strategies are recommended:

- Implementing second-layer solutions or sidechains to improve scalability.
- Adopting standard protocols and open APIs to enhance interoperability.
- Utilizing advanced encryption and smart contracts to safeguard personal data.

In addition to technical solutions, the literature emphasizes the importance of a robust governance framework. This framework should define usage policies, participant roles, and consensus mechanisms tailored to the specific operational context of HEIs.

Key finding 3

The absence of standardized governance models is a significant limiting factor in BCT adoption, underscoring the need for institutional policies that evolve in tandem with technological advancements.

Ultimately, the successful integration of BCT in HEIs is projected to yield not only improved efficiency and security in academic processes but also foster educational innovation and interinstitutional collaboration.

Key finding 4

When supported by strategic planning and adaptive governance, BCT can serve as a catalyst for sustainable and resilient academic ecosystems.

UCE-Camp proposal as a sustainable university model

Considering proposals such as the one described in Ayman et al. (2023), the authors propose a sustainable University model by incorporating new functionalities and services that enhance the value and utility of a BCT-based application for users and interested parties within the academic community. The five Phases must be considered as described in Table 6.

Table 6

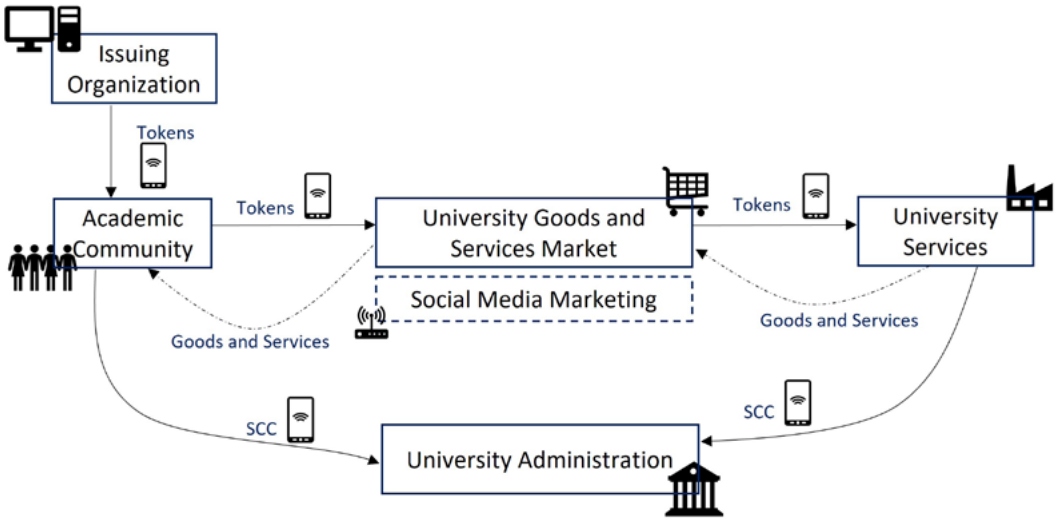
Phases of the proposal

PHASE	DESCRIPTION
Phase 1	Analysis of the needs, objectives and requirements of users and interested parties of the UCE-Camp platform, through surveys, interviews and participatory workshops
Phase 2	Design of the new functionalities and services that will be incorporated into the UCE-Camp platform, using prototyping, modeling and simulation techniques

PHASE	DESCRIPTION
Phase 3	Implementation and testing of the new functionalities and services that will be incorporated into the UCE-Camp platform, using agile methodologies, automated testing and code reviews
Phase 4	Deployment and dissemination of the new functionalities and services that will be incorporated into the UCE-Camp platform, using effective strategies and channels for the promotion, training and support of users and interested parties.
Phase 5	Monitoring and improvement of new functionalities and services that will be incorporated into the UCE-Camp platform, using indicators and feedback mechanisms to measure performance, satisfaction and impact of the platform

The purpose of the model is to promote sustainable actions within the university environment and will allow the exchange of goods and services within the academic community. Such actions could be framed as support in tutoring, volunteering, serving as support chairs, publications, participating in research, among others. In turn, these activities will be rewarded with tokens that will be used to acquire goods or services provided by the University, such as courses, training, and laboratory time, among others. The general scheme is presented in Figure 4.

Figure 4
UCE-Camp Proposal



This proposal must also overcome several challenges, such as those described in previous sections, particularly related to:

- Enhance awareness, understanding, and confidence in BCT-based technology and new application among users and stakeholders.
- Establish standards, norms, and regulations that ensure interoperability, compatibility, and compliance of automation rules with legal and ethical requirements, through collaboration with relevant authorities and organizations.
- Optimize infrastructure, resources, and technical capabilities efficiently and securely to implement, maintain, and scale BCT technology and the UCE-Camp platform by adopting appropriate best practices and associated technologies.
- Generate evidence, evaluation, and validation of the impacts and results of BCT technology and the UCE-Camp platform on the quality, equity, and effectiveness of higher education, through the use of indicators and feedback mechanisms.

As an implementation strategy, we must consider:

- Research and Development:
  - Feasibility Study: Conduct a study to assess the technical and economic feasibility of implementing the UCE-Camp platform, which considers a social cryptocurrency in the university context.
  - Prototype Development: Create a prototype of the cryptocurrency based on blockchain technology, ensuring that it is secure, scalable, and complies with legal requirements.
- Integration with University Infrastructure:
  - Exchange Platform: Develop the UCE-Camp exchange platform within the university that allows students and staff to buy, sell, or exchange goods and services using cryptocurrency.
  - Reward Systems: Implement reward systems to incentivize behaviors that contribute to sustainable development, such as recycling, volunteering, or participation in sustainable research projects.
- Cooperation and Alliances:
  - Strategic Alliances: Establish alliances with local businesses and organizations that accept the cryptocurrency, thereby extending its use beyond the university campus.
  - Joint Projects: Promote joint projects between the university and the community to solve local problems using cryptocurrency as a means of financing.
- Education and Awareness:
  - Educational Programs: Incorporate courses and workshops on cryptocurrencies, blockchain, and sustainable development into the university curriculum, with an emphasis on the UCE-Camp platform.
  - Awareness Campaigns: Launch campaigns to educate the university community about the benefits and responsible use of social cryptocurrencies, as well as familiarize them with the UCE-Camp platform.
- Evaluation and Scalability:
  - Monitoring and Evaluation: Establish monitoring mechanisms to assess the impact of cryptocurrency on the university community and its contribution to sustainable development goals.
  - Scalability Plans: Develop plans to scale the cryptocurrency, allowing its adoption in other universities and communities.
- Technical Issues and Feasibility:
  - Cybersecurity: Ensuring protection against cyberattacks is fundamental to trust in the cryptocurrency; therefore, the UCE-Camp platform must be robust.
  - Interoperability: Ensure that the cryptocurrency can interact with other digital currencies and payment systems.
  - Adoption and use: Encouraging widespread adoption among potential users is a key challenge to the project's success.
  - Regulation and Compliance: Navigate the regulatory landscape to ensure compliance with financial and cryptocurrency laws.

This initial model must be refined to determine the scope and limitations in greater detail, prior to building a deployment or pilot prototype. In this context, thesis prototypes have been developed to exploit the benefits of BCT technology in HEI. Thus, Pazmiño (2023) proposes a social cryptocurrency model that promotes collaborative and sustainable activities in an academic environment. Similarly, Alpala (2024) proposes the use of an ERC-20 token-based cryptocurrency to promote environmental awareness and incentivize this behavior in the university community.

Discussion and Conclusions

The findings of this research, grounded in an up-to-date systematic review, have enabled the identification of the most relevant proposals and application models of blockchain technology (BCT) in academic processes, particularly within higher education institutions. The reviewed literature primarily focuses on secure certificate issuance and the enhancement of teaching and learning environments, although other domains have also been addressed. Key benefits include the prevention of errors, fraud, and corruption in processes such as academic record management, degree verification, and plagiarism detection. Moreover, blockchain ensures data integrity, strengthens information security, and validates the authenticity of issued documents.

Despite these advantages, practical implementations remain limited and have predominantly concentrated on certificate management platforms. The application of BCT in education is still in an emerging phase, with a clear gap between identified institutional needs and effective deployment. Adoption faces technical, organizational, and cultural challenges; however, the potential benefits justify continued exploration and the development of innovative solutions.

The main contribution of this study lies in its dual approach: it offers a comprehensive and current systematic review that provides insight into the state of blockchain technology in higher education, and it introduces the UCE-Camp model as a sustainable and applicable solution to improve efficiency, transparency, and quality of academic processes. Unlike previous studies that remain conceptual or focus on isolated cases, this research translates existing knowledge into a concrete proposal aligned with contemporary institutional demands.

The UCE-Camp model represents a strategic opportunity to transform the educational ecosystem by promoting more inclusive, collaborative, and autonomous academic management. Nonetheless, certain limitations must be acknowledged, such as the lack of longitudinal studies and the absence of real-world implementations, which hinder a complete assessment of their effectiveness. Additionally, issues such as system interoperability, technological scalability, and institutional acceptance continue to be significant barriers.

For future research, it is recommended that the UCE-Camp model be piloted to assess its technical, organizational, and cultural feasibility in real-world settings. This implementation should consider integration with online courses, digital certifications, academic portfolios, and social networks, thereby enriching the user learning experience. Furthermore, it is essential to explore new applications of blockchain technology in areas such as research management, innovation and knowledge transfer, institutional governance, administrative transparency, and data protection. These research directions will contribute to the continuous improvement of quality and excellence in higher education.

Acknowledgements and Declarations

The authors declared that, in the preparation of this article, AI tools were no used.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

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